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Chlorantraniliprole at sublethal concentrations may reduce the population growth of the Asian corn borer, *Ostrinia furnacalis* (Lepidoptera: Pyralidae)

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Abstract: In order to provide a scientific basis for understanding the effects of the insecticide chlorantraniliprole on *Ostrinia furnacalis* (Guenée), diet-incorporation bioassays were used to examine the toxicity of chlorantraniliprole to *O. furnacalis*, and the sublethal effects of the insecticide were investigated using life table analyses under laboratory conditions. The results showed that the LC_{10}, LC_{40}, and LC_{50} values of chlorantraniliprole on the 3rd instar larvae of *O. furnacalis* were 0.038, 0.098, and 0.123 mg a. i./L, respectively. After the 3rd instar larvae were treated with LC_{10} and LC_{40} levels of chlorantraniliprole, the larval and pupal development were significantly delayed, adult longevity was significantly decreased and fecundity also decreased compared to the control, but the pupal weight (female: $P = 0.337$, male: $P = 0.121$), egg hatchability ($P = 0.087$) and sex ratio ($P = 0.379$) were not affected. Reproduction parameters, such as the net reproductive rate (R_0), intrinsic rate of increase (r_m), and finite rate of increase (λ) in the treatment groups were significantly lower than those in the control group. These results suggest that the LC_{10} and LC_{40} concentrations of chlorantraniliprole may reduce the population growth of *O. furnacalis*.

Keywords: *Ostrinia furnacalis*; chlorantraniliprole; sublethal effects; biological parameters; toxicity

1 INTRODUCTION

The Asian corn borer, *Ostrinia furnacalis* (Guenée) (Lepidoptera: Pyralidae), is one of the most economically important corn stalk-boring pests in Asia. Because the insect live inside its host plant for most of its life cycle, controlling the Asian corn borer has proven to be quite difficult. Pesticides are widely used against the corn borer, but when insufficient amounts of an insecticide reach the active sites of pests, only sublethal effects occur. Sublethal effects include alterations to the physiological and behavioral characteristics of insects (Haynes, 1988), but not immediate death. Sublethal concentration of a substance can influence the development time, pupal weight, adult longevity, mating behavior, egg hatchability, fecundity, egg size, and sex ratio (Yang and Du, 2003; Pineda *et al.*, 2007; Yin *et al.*, 2008; Teixeira *et al.*, 2009; Wang *et al.*, 2009; Sial and Brunner, 2010; Mahmoudvand *et al.*, 2011; Alizadeh *et al.*, 2012). However, sublethal doses of insecticides frequently cause resurgence of a pest population through physiological and ecological mechanisms (Ripper, 1956; Luckey, 1968). Hence, a thorough investigation of the sublethal effects associated with pesticides is critical for determining the efficacy and assessing the risk of pesticide treatments (Desneux *et al.*, 2007).

Chlorantraniliprole is a new anthranilic diamide insecticide developed by DuPont Crop Protection. This insecticide has been proven effective against a number of lepidopteran pest species (Cao *et al.*, 2010; Sial and Brunner, 2010). However, the effects of chlorantraniliprole on *O. furnacalis* have not yet been reported. In this study, we determined how chlorantraniliprole affects the surviving *O. furnacalis* individuals when the 3rd instar larvae were exposed to different concentrations of pesticides for 120 h. Here, we presented the effects of exposure on several characteristics, including developmental time, pupal weight, sex ratio, adult longevity, fecundity, and egg hatchability, and evaluated the key population growth parameters as well.

2 MATERIAL AND METHODS

2.1 Test insects

The initial *O. furnacalis* population was

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collected in August 2008 from corn crops in Luoyang, Henan Province, China. This colony was reared continuously on the artificial diet described by Zhou *et al.* (1980). Insect stock was maintained at 28 ± 1℃, 70% ± 5% relative humidity (RH) and a photoperiod of 16L: 8D in a growth chamber.

2.2 Insecticide

The insecticide chlorantraniliprole (20% SC, Rynaxypyr) used in this study was purchased from DuPont Crop Protection.

2.3 Bioassays to determine the sublethal concentrations

The toxicity of chlorantraniliprole to the 3rd instar larvae of *O. furnacalis* was estimated using a diet-incorporation bioassay. Newly moulted (starved for 0 – 5 h) 3rd instar larvae were continuously fed with an artificial diet containing one of seven concentrations (0.500, 0.333, 0.250, 0.125, 0.063, 0.042, or 0.033 mg a. i./L) of the insecticide. Serial dilutions to make the different concentrations were prepared in 20 mL of water and mixed into the diet after it had cooled to ~50℃. Treated diet was refrigerated (4℃) for no longer than 48 h before being used or discarded. At least 30 larvae were randomly selected and individually placed into small glass finger tubes (1.8 cm in diameter, and 8 cm in depth) containing ~1 cm^3 of insecticide-treated diet. Untreated diet was provided to individuals in the control group. These tests were repeated four times. The diet was replaced periodically as necessary. Insect mortality was evaluated at 120 h after the initial exposure. Larvae were recorded as dead if they could not move when probed with an ink brush.

According to the bioassay results, the LC_{10} and LC_{40} values at 120 h after exposure were selected as the sublethal concentrations for subsequent experiments.

2.4 Exposure of *O. furnacalis* larvae to sublethal concentrations of chlorantraniliprole

Artificial diets spiked with LC_{10} and LC_{40} concentrations of chlorantraniliprole and control diets were prepared as described above. The 3rd instar larvae of *O. furnacalis* were obtained from the stock culture and starved for 0 – 5 h and then individually placed in finger tubes containing diet treated with different concentrations of chlorantraniliprole or untreated diet (control). Larvae were maintained at 28 ± 1℃, 70% ± 5% RH, and a 16L : 8D photoperiod in a climate chamber. After 120 h, live larvae were transferred to a tube containing untreated artificial diet and allowed to continue their development into the pupal stage. Pupae were placed individually in plastic cups (250 mL) until adults emerged. Individual 3-day-old pupae in each treatment group were selected to be weighted and sexed. After they became adults, individuals exposed to each sublethal concentration and those in the control group were selected, and each pair (male and female) was introduced into a mating cage (10 cm in diameter, and 18 cm in depth). A sugar solution (10%) was used to feed the adult moths and was replaced every 2 d to prevent fungal growth. For each mating pair, the fecundity, percentage of eggs hatched (egg hatchability), and moth longevity were recorded.

2.5 Data analysis

Mortality data from the larval toxicity bioassays underwent probit regression analysis against log (insecticide concentration). The experimental data were subjected to one-way analysis of variance (ANOVA) ($P < 0.05$) after checking for normality. Means were compared using Tukey's range test, admitting significant differences at $P < 0.05$. Differences in biological parameters were tested using the jackknife method (Tao and Wu, 2006). SPSS software was used for all analyses (SPSS Institute 17.0).

3 RESULTS AND ANALYSES

3.1 Toxicity of chlorantraniliprole to the 3rd instar larvae of *O. furnacalis*

The estimated LC_{50} from a diet-incorporation bioassay on the 3rd instar larvae of *O. furnacali* at 120 h after treatment was 0.123 mg a. i./L, and the LC_{10} and LC_{40} values were 0.038 mg a. i./L and 0.098 mg a. i./L, respectively (Table 1). The results from this bioassay indicate that chlorantraniliprole showed excellent activity against *O. furnacalis* individuals collected in Henan.

Table 1　Toxicity of chlorantraniliprole to the 3rd larvae of *Ostrinia furnacalis* at 120 h after treatment

	df	LC_{10}	LC_{40}	LC_{50}	Slope ± *SE*	χ^2	*P* value
Chlorantraniliprole	4	0.038 (0.024 – 0.051)	0.098 (0.077 – 0.119)	0.123 (0.100 – 0.151)	2.514 ± 0.324	1.775	0.062

3.2 Sublethal effects of chlorantraniliprole on developmental duration and adult longevity of *O. furnacalis*

The effects of chlorantraniliprole at sublethal concentrations on the larval, prepupal and pupal duration and on the adult longevity of *O. furnacalis* are presented in Table 2. Both LC_{10} and LC_{40} concentrations of chlorantraniliprole significantly increased the larval and pupal duration (larval: $F = 155.93$, $P < 0.0001$, $df = 2, 487$; pupal: $F = 15.01$, $P < 0.0001$, $df = 2, 262$). Pre-pupal duration in the LC_{40} treatment group was significantly longer than that in the control group ($F = 8.54$, $P < 0.0001$, $df = 2, 299$). The mean life time of males and females in LC_{40} treatment group were significantly shorter than that in the control; However, the mean life time of females in LC_{10} treatment group was significantly longer than that in the control group (male: $F = 16.68$, $P < 0.0001$, $df = 2, 72$; female: $F = 11.27$, $P < 0.0001$, $df = 2, 65$).

3.3 Sublethal effects of chlorantraniliprole on pupal weight, fecundity, egg hatchability, sex ratio of *O. furnacalis*

Table 3 shows the sublethal effects of chlorantraniliprole on fecundity, egg hatchability, sex ratio, and pupal weight of *O. furnacalis*. Chlorantraniliprole at sublethal concentrations significantly reduced the fecundity of *O. furnacalis* ($F = 4.835$, $P = 0.013$, $df = 2, 39$). However, chlorantraniliprole had no effect on egg hatchability ($F = 3.31$, $P = 0.087$, $df = 2, 597$) or on the sex ratio ($F = 1.15$, $P = 0.379$, $df = 2, 6$). In addition, pupal weight in the LC_{10} treatment group, the LC_{40} group and the untreated group were not significantly different (male: $F = 2.16$, $P = 0.121$, $df = 2, 145$; female: $F = 1.10$, $P = 0.337$, $df = 2, 152$).

Table 2 Sublethal effects of chlorantraniliprole on larval, prepupal and pupal duration (d), and adult longevity (d) of *Ostrinia furnacalis* at 120 h after treatment to the 3rd instar larvae

Chlorantraniliprol concentration	Larval duration	Prepupal duration	Pupal duration	Adult longevity	
				Female	Male
0 (Control)	14.25 ±0.33 c(90)	1.32 ±0.10 b(90)	6.63 ±0.22 c(90)	12.25 ±0.60 b(20)	10.73 ±0.85 a(21)
LC_{10}	19.73 ±0.21 b(150)	1.46 ±0.10 b(117)	7.37 ±0.19 b(90)	14.60 ±0.65 a(25)	10.84 ±0.70 a(25)
LC_{40}	22.22 ±0.22 a(250)	1.91 ±0.09 a(95)	8.03 ±0.09 a(85)	8.17 ±0.73 c(23)	6.34 ±0.52 b(29)
P	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
F	155.93	8.54	15.01	11.27	16.68
df	2,487	2,299	2,262	2,65	2,72

Larval duration indicate the number of days from egg hatching to prepupa. All values are means ± *SE*; means marked with different letters within the same column are significantly different ($P < 0.05$; Tukey's test). Numbers in brackets show the number of individuals measured. The same below.

Table 3 Comparison of pupal weight, fecundity, egg hatchability, and sex ratio in *Ostrinia furnacalis* treated with sublethal concentrations of chlorantraniliprole and in untreated controls at 120 h after treatment

Chlorantraniliprol concentration	Pupal weight (g)		Fecundity (number of eggs laid per female)	Egg hatchability (%)	Proportion of females (%)
	Male	Female			
0 (Control)	0.066 ±0.003 a(37)	0.099 ±0.004 a(35)	587.21 ±81.37 a	91.94 ±0.91 a(826)	49.69 ±0.54 a
LC_{10}	0.073 ±0.002 a(40)	0.105 ±0.002 a(40)	346.15 ±46.97 b	90.57 ±1.67 a(737)	50.55 ±0.53 a
LC_{40}	0.073 ±0.002 a(35)	0.103 ±0.002 a(32)	321.47 ±65.53 b	89.10 ±2.29 a(644)	49.49 ±0.51 a
P	0.121	0.337	0.013	0.087	0.379
F	2.16	1.10	4.835	3.31	1.15
df	2,145	2,152	2,39	2,597	2,6

3.4 Sublethal effects of chlorantraniliprole on population growth parameters of *O. furnacalis*

The population growth parameters of *O. furnacalis* were significantly affected by chlorantraniliprole (Table 4). The net reproduction rate (R_0) significantly differed between the control group and groups exposed to sublethal insecticide concentrations ($F = 125.03$, $P < 0.0001$, $df = 2, 57$). The rate increase (r_m) in treatment groups of LC_{10} and LC_{40} of chlorantraniliprole was significantly lower than that in the control group ($F = 74.33$, $P < 0.0001$, $df = 2, 57$). LC_{10} and LC_{40} of chlorantraniliprole also had significant effects on the finite rate of increase (λ) ($F = 81.33$, $P < 0.0001$, $df = 2, 57$). The generation time (T) and doubling time (t) in treatment groups at the two sublethal concentrations were significantly increased compared with the control group (T: $F = 1\,969.85$, $P < 0.0001$, $df = 2, 57$; t: $F = 669.96$, $P < 0.0001$, $df = 2, 57$).

Table 4 Comparison of biological parameters of *Ostrinia furnacalsi* treated with chlorantraniliprole and the control group at 120 h after treatment

Chlorantraniliprol concentration	Parameters				
	R_0	r_m (d^{-1})	λ (d^{-1})	T (d)	t (d)
0 (Control)	154.92 ±6.20 a	0.16 ±0.00 a	1.18 ±0.00 a	30.42 ±0.06 c	4.16 ±0.07 c
LC_{10}	125.06 ±3.91 b	0.14 ±0.00 b	1.16 ±0.00 b	33.33 ±0.10 b	4.82 ±0.03 b
LC_{40}	61.46 ±1.63 c	0.11 ±0.00 c	1.12 ±0.00 c	37.73 ±0.08 a	6.34 ±0.00 a
P	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
F	125.03	74.33	81.33	1969.85	669.96
df	2,57	2,57	2,57	2,57	2,57

4 DISCUSSION

Chlorantraniliprole, an insecticide that uses a novel mode of action, potently activates the ryanodine receptors in insect muscles, which release the stored calcium from the sarco/endoplasmic reticulum and causes problems regulating muscle contractions, leading to feeding cessation, lethargy, and muscle paralysis (Cordova *et al.*, 2006). The efficacy of the insecticide is slow, but the effects last for a long time. Based on the report by Lai and Su (2011) and trial tests performed in our laboratory (unpublished data), we chose 120 h as the test time of virulence. The data obtained in this study showed that chlorantraniliprole was highly active against *O. furnacalis*, with an LC_{50} of 0.123 mg a.i./L. This result was in good agreement with Lahm *et al.* (2007), which reported the high toxicity of this chemical when applied to several lepidopteran pests.

Many previous studies have reported that the larval duration were prolonged when exposed to sublethal concentrations of chlorantraniliprole (Teixeira *et al.*, 2009; Lai and Su, 2011; Han *et al.*, 2012). These findings agree well with our results, which showed that the larval duration was delayed by 38.46% and 55.93% compared to controls when larvae were treated with LC_{10} and LC_{40} concentrations of chlorantraniliprole, respectively. One reason for the developmental delay was that the balance between development and detoxification in the larvae shifted toward detoxification, meaning that resources were spent on detoxification rather than development, causing larval development to take significantly longer time than in the control group. Another reason for the developmental delay was perhaps due to starvation caused by feeding cessation (Hannig *et al.*, 2009). Lai and Su (2011) reported that neonate *Spodoptera exigua* larvae exposed to chlorantraniliprole at LC_{30} and LC_{50} levels did not show significant differences in their duration in the pupal stage. However, our results showed that pupal duration was prolonged in the treatment groups compared to the control group. Most insecticides studied have been found to reduce adult longevity (Stapel *et al.*, 1998; Wang *et al.*, 2009; Mahmoudv *et al.*, 2011). In our study, the adult longevity in *O. furnacalis* was significantly decreased in the LC_{40} group compared to the control group, but adult longevity in the LC_{10} group was significantly prolonged. Perhaps this unexpected finding occurred because of the relatively small sample size used in this analysis.

There have been many reports on pupal weight reduction after insects had been exposed to sublethal level of insecticides (Seth *et al.*, 2004; Pineda *et al.*, 2007; Rodríguez Enríquez *et al.*, 2010). However, a different study showed that pupal weight increased after neonate *S. exigua* larvae were exposed to sublethal levels of chlorantraniliprole (Lai and Su, 2011). Our results showed no significant difference in pupal weight, regardless of the exposure conditions. Observations on the behavior of Asian corn borer larvae showed that chlorantraniliprole decreased the mobility of larvae, but most of the larvae exposed to lower concentrations of the insecticide recovered once they were removed from insecticide condition. In these instances, larvae gained weight rapidly after removal from the insecticide environment, so pupal weight was not affected.

Studies have demonstrated that when the 3rd instar larvae of *Platynota idaeusalis* were exposed to tebufenozide, the fecundity or fertility were not affected

(Biddinger, 2006). In contrast, marked reductions in fecundity and fertility were observed in *S. littoralis* and *S. litura* that had been treated with RH-5849, tebufenozide, or methoxyfenozide during the larval stages (Seth *et al.*, 2004; Pineda *et al.*, 2007). Previous studies have shown that chlorantraniliprole significantly disrupted the mating behavior of *Cydia pomonella* and had significant ovicidal activity on *Lobensia botrana* (Knight and Flexner, 2007; Ioriatti *et al.*, 2009). In our study, the LC_{10} and LC_{40} concentrations of chlorantraniliprole had no significant effect on the fertility of *O. furnacalis* but significantly reduced the fecundity. In order to thoroughly assess the sublethal effects of chlorantraniliprole on the reproduction of *O. furnacalis*, further assays on the older larvae, pupae, and adults should be conducted.

We observed that chlorantraniliprole exposure did not affect the sex ratios of *O. furnacalis* pupae. Similarly, this compound was not found to affect the sex ratios of exposed *S. exigua* neonates (Lai and Su, 2011) or the 3rd instar larvae of *Rhagoletis* fruit flies (Teixeira *et al.*, 2009). Currently, chlorantraniliprole does not seem to affect the sex ratios of treated insects.

The sublethal effects of insecticides vary widely among and within different insect species. These differences may arise because of differences in the species, different exposure methods, or even different concentrations of insecticides used (Hannig *et al.*, 2009). The developmental stage of insects at the time of exposure may also contribute to how sublethal effects are presented. However, one study suggested that the sublethal effects of insecticides are more dependent on their application dose/concentration rather than the class of insecticide used or the insect species affected (Yin *et al.*, 2008).

Morse and Zareh (1991) observed that the insecticide malathion significantly increased fecundity in citrus thrips, *Scirtothrips citri*. Kerns and Stewart (2000) reported that exposing *Myzus persicae* to sublethal concentrations of bifenthrin increased their net reproductive rate and nymphal production. Contrary to these findings, Lashkari *et al.* (2007) reported that intrinsic rates of increase in cabbage aphids were lower in populations treated with sublethal concentrations of imidacloprid and pymetrozine than in the controls. Golmohammadi *et al.* (2009) found that indoxacarb decreased R_0 but did not decrease r_m or λ in *Chrysoperla carnea*. In this study, the larval duration tended to be longer in the treatment groups than in the control group. Therefore, the mean generation time of *O. furnacalis* was prolonged. The mean values of the intrinsic rate of increase (r_m), the net reproductive rate (R_0), and the finite rate of increase (λ) were significantly lower in the LC_{10} and LC_{40} groups than in the control group. It is, therefore, possible that chlorantraniliprole has sublethal effects on *O. furnacalis* that may affect population dynamics in the field via reductions in their survival and reproduction.

References

Alizadeh M, Karimzadeh J, Rassoulian GR, Farazmand H, Hoseini-Naveh V, Pourian HR, 2012. Sublethal effects of pyriproxyfen, a juvenile hormone analogue, on *Plutella xylostella* (Lepidoptera: Plutellidae): life table study. *Archives of Phytopathology and Plant Protection*, 45(14): 1741 – 1763.

Biddinger D, Hull L, Huang H, McPheron B, Loyer M, 2006. Sublethal effects of chronic exposure to tebufenozide on the development, survival, and reproduction of the tufted apple bud moth (Lepidoptera: Tortricidae). *J. Econ. Entomol.*, 99(3): 834 – 842.

Cao GC, Lu Q, Zhang LL, Guo F, Liang GM, Wu KM, Wyckhuys KAG, Guo YY, 2010. Toxicity of chlorantraniliprole to Cry1Ac-susceptible and resistant strains of *Helicoverpa armigera*. *Pestic. Biochem. Physiol.*, 98: 99 – 103.

Cordova D, Benner EA, Sacher MD, Rauh JJ, Sopa JS, Lahm GP, Selby TP, Stevenson TM, Flexner L, Gutteridge S, Rhoades DF, Wu L, Smith RM, Tao Y, 2006. Anthranilic diamides: a new class of insecticides with a novel mode of action, ryanodine receptor activation. *Pestic. Biochem. Physiol.*, 84: 196 – 214.

Desneux N, Decourtye A, Delpuech JM, 2007. The sublethal effects of pesticides on beneficial arthropods. *Annu. Rev. Entomol.*, 52: 81 – 106.

Golmohammadi Gh, Hejazi M, Iranipour Sh, Mohammadi SA, 2009. Lethal and sublethal effects of endosulfan, imidacloprid and indoxacarb on first instar larvae of *Chrysoperla carnea* (Neu.: Chrysopidae) under laboratory conditions. *Journal of Entomological Society of Iran*, 28(2): 37 – 47.

Han WS, Zhang SF, Shen FY, Liu M, Ren CC, Gao XW, 2012. Residual toxicity and sublethal effects of chlorantraniliprole on *Plutella xylostella* (Lepidoptera: Plutellidae). *Pest Manag. Sci.*, 68(8): 1184 – 1190.

Hannig GT, Ziegler M, Marcon PG, 2009. Feeding cessation effects of chlorantraniliprole, a new anthranilic diamide insecticide, in comparison with several insecticides in distinct chemical classes and mode-of-action groups. *Pest Manag. Sci.*, 65(9): 969 – 974.

Haynes KF, 1988. Sublethal effects of neurotoxic insecticides on insect behavior. *Ann. Rev. Entomol.*, 33: 149 – 168.

Ioriatti C, Anfora G, Angeli G, Mazzoni V, Trona F, 2009. Effects of chlorantranilipole on eggs and larvae of *Lobesia botrana* (Denis & Schiffermüller) (Lepidoptera: Tortricidae). *Pest Manag. Sci.*, 65(6): 717 – 722.

Kerns DL, Stewart SD, 2000. Sublethal effects of insecticides on the intrinsic rate of increase of cotton aphid. *Entomol. Exp. Appl.*, 94: 41 – 49.

Knight AL, Flexner L, 2007. Disruption of mating in codling moth (Lepidoptera: Tortricidae) by chlorantranilipole, an anthranilic diamide insecticide. *Pest Manag. Sci.*, 63: 180 – 189.

Lahm GP, Stevenson TM, Selby TP, Freudenberger JH, Cordova D, Flexner L, Bellin CA, Dubas CM, Smith BK, Hughes KA, Hollingshaus JG, Clark CE, Benner EA, 2007. Rynaxypyr^{TM}: a new insecticidal anthranilic diamide that acts as a potent and selective ryanodine receptor activator. *Bioorg. Med. Chem. Lett.*, 17(22): 6274 – 6279.

Lai TC, Su JY, 2011. Assessment of resistance risk in *Spodoptera exigua* (Hübner) (Lepidoptera: Noctuidae) to chlorantraniliprole. *Pest Manag. Sci.*, 67(11): 1468 – 1472.

Lashkari MR, Sahragard A, Ghadamyri M, 2007. Sublethal effects of imidacloprid and pymetrozine on population growth parameters of cabbage aphid, *Brevicoryne brassicae* on rapeseed, *Brassica napus* L. *Insect Sci.*, 14: 207 – 212.

Luckey TD, 1968. Insecticide hormoligosis. *J. Econ. Entomol.*, 61: 7 – 12.

Mahmoudv M, Abbasipour H, Garjan AS, Bandani AR, 2011. Sublethal

effects of indoxacarb on the diamondback moth, *Plutella xylostella* (L.) (Lepidoptera: Yponomeutidae). *Appl. Entomol. Zool.*, 46: 75 -80.

Morse JG, Zareh N, 1991. Pesticide-induced hormoligosis of citrus thrips (Thysanoptera: Thripidae) fecundity. *J. Econ. Entomol.*, 84(4): 1169 -1174.

Pineda S, Schneider MI, Smagghe G, Martínez AM, Estal PD, Viñuela E, Valle J, Budia F, 2007. Lethal and sublethal effects of methoxyfenozide and spinosad on *Spodoptera littoralis* (Lepidoptera: Noctuidae). *J. Econ. Entomol.*, 100(3): 773 -780.

Ripper WE, 1956. Effect of pesticides on balance of arthropod populations. *Annu. Rev. Entomol.*, 1: 403 -438.

Rodríguez Enríquez CL, Pineda S, Figueroa JI, Schneider MI, Martínez AM, 2010. Toxicity and sublethal effects of methoxyfenozide on *Spodoptera exigua* (Lepidoptera: Noctuidae). *J. Entomol.*, 103 (3): 662 -667.

Seth RK, Kaur JJ, Rao DK, Reynolds SE, 2004. Effects of larval exposure to sublethal concentrations of the ecdysteriod agonists RH-5849 and tebufenozide (RH-5992) on male reproductive physiology in *Spodoptera litura*. *J. Insect Physiol.*, 50(6): 505 -517.

Sial AA, Brunner JF, 2010. Lethal and sublethal effects of an insect growth regulator, pyriproxyfen, on obliquebanded leafroller (Lepidoptera: Tortricidae). *J. Econ. Entomol.*, 103 (2): 340 -347.

Stapel JO, Waters DJ, Ruberson JR, Lewis WJ, 1998. Development and behavior of *Spodoptera littoralis* (Lepidoptera: Noctuidae) larvae in choice tests with food substrates containing toxins of *Bacillus thuringiensis*. *Biol. Control*, 11: 29 -37.

Tao SQ, Wu FA, 2006. VFP program on variance of life table parameters using jackknife technique. *Chinese Bulletin of Entomology*, 43(2): 262 -265. [陶士强, 吴福安, 2006. 应用Jackknife技术统计昆虫生命表参数变异的VFP实现. 昆虫知识, 43(2): 262 -265]

Teixeira LAF, Gut LJ, Wise JC, Isaacs R, 2009. Lethal and sublethal effects of chlorantraniliprole on three species of *Rhagoletis* fruit flies (Diptera: Tephritidae). *Pest Manag. Sci.*, 65: 137 -143.

Wang D, Gong PY, Li M, Qiu XH, Wang KY, 2009. Sublethal effects of spinosad on survival, growth and reproduction of *Helicoverpa armigera* (Lepidoptera: Noctuidae). *Pest Manag. Sci.*, 65: 223 -227.

Yang ZH, Du JW, 2003. Effects of sublethal deltamethrin on the chemical communication system and PBAN activity of Asian corn borer, *Ostrinia furnacalis* (Güenee). *J. Chem. Ecol.*, 29 (7): 1611 -1619.

Yin XH, Wu QJ, Li XF, Zhang YJ, Xu BY, 2008. Sublethal effects of spinosad on *Plutella xylostella* (Lepidoptera: Yponomeutidae). *Crop Protection*, 27(10): 1385 -1391.

Zhou DR, Wang YY, Liu BL, Ju ZL, 1980. Study on the mass rearing of corn borer. Ⅰ. Development of a satisfactory artificial diet for larval growth. *Acta Phytophylacica Sinica*, 7(2): 113 -122. [周大荣, 王玉英, 刘宝兰, 剧正理, 1980. 玉米螟人工大量繁殖研究: Ⅰ. 一种半人工饲料及其改进. 植物保护学报, 7(2): 113 -122]

死浓度氯虫苯甲酰胺可降低亚洲玉米螟的种群增长

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摘要: 为了探讨氯虫苯甲酰胺对亚洲玉米螟 *Ostrinia furnacalis* (Guenée)的抗性风险评估, 为科学使用氯虫苯甲酰胺防治亚洲玉米螟提供理论基础, 本研究在实验室条件下采用饲料混毒法测定了新型杀虫剂氯虫苯甲酰胺对亚洲玉米螟的毒力, 利用生命表技术研究了氯虫苯甲酰胺对亚洲玉米螟3龄幼虫的亚致死效应。结果表明: 氯虫苯甲酰胺对亚洲玉米螟3龄幼虫的 LC_{10}, LC_{40}和 LC_{50}分别为0.038, 0.098 和0.123 mg a. i. /L。以氯虫苯甲酰胺 LC_{10}和 LC_{40}剂量分别处理亚洲玉米螟3龄幼虫后, 幼虫和蛹的发育历期明显延长, 成虫寿命缩短, 产卵量也显著降低, 但对蛹重(雌: $P=0.337$, 雄: $P=0.121$)、卵孵化率($P=0.087$)和性比($P=0.379$)无显著影响。处理种群的净增值率(R_0)、内禀增长率(r_m)和周限增长率(λ)显著低于对照种群($P<0.0001$)。结果提示, 氯虫苯甲酰胺的亚致死浓度可降低亚洲玉米螟的种群增长。

关键词: 亚洲玉米螟; 氯虫苯甲酰胺; 亚致死效应; 生命表参数; 毒性

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